The Mistry-Hyper Guitar

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A portfolio of original compositions and commentary submitted to the University of Huddersfield in partial fulfilment of the requirements for the MA by research.

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Contents

Abstract

This research project describes the research and building of an ergonomically designed electric guitar that extends the capabilities for composition and performance on guitar by integrating sensors in to the construction of the instrument. The Mistry-hyper-guitar integrates and extends traditional playing techniques. The instrument controls physically modelled sounds, triggers samplers and creates controller messages for sound and effects manipulation utilising sensor technology ergonomically positioned around the guitar body. The shape of the body is designed to encourage good posture and correct positioning of both the left and right hands in order to promote comfort and ease of playing both the strings and sensors during performance.

I will examine and describe the development of the instrument and the techniques required to play the instrument. The creative portfolio will comprise a 25-minute composition created to demonstrate the capabilities of the instrument.

Introduction

The Electro String Company founded by Adolph Rickenbacker, George Beauchamp and Paul Barth introduced the first commercially available electric guitar in 1931. The guitar was named the Frying Pan (see Figure 1) and utilised a pickup (see Figure 2) that consisted of two horseshoe magnets that acted as a transducer. The strings passed through the magnets and over a coil, which had six pole pieces concentrating the magnetic field under each string. This converted the vibrations of the strings into an electrical current that was then passed through an amplifier to a speaker.

Figure 1: The Frying pan[1]

[1] www.axewar.com/electric_guitar_pics.php5?page=2&find=electric

Figure 2: Horse Shoe magnet pickup[2]

The development of the electric guitar into a mass-market product became possible when in 1950, Leo Fender launched the Fender Broadcaster (see Figure 3), which in 1951 was renamed the Fender Telecaster, a name that is still in use today. This guitar was unique at the time as it had a solid wooden body and a bolt on neck. This combination meant that the manufacturing process was much simpler in comparison to traditional guitars and enabled large numbers of units to be produced efficiently. This meant the cost of each instrument could be kept low, an important factor that facilitated the electric guitar becoming one of the most popular instruments in modern music history. Another important guitar that should be mentioned is the Fender Stratocaster. This instrument has three single coil pickups, a combined adjustable bridge /tremolo unit and a contoured body for player comfort. The first Stratocaster was brought to market in 1954 and has become the most popular and emulated solid bodied guitar (see Figure 4).

[2] http://www.vintagemartin.com/Rickenbacher.html

Figure 3: Fender Broadcaster[3]

Figure 4: Fender Stratocaster[4]

[3] www.theguitarcolumn.com/2010/04/leon-mcauliffes-1950-fender-broadcaster.html

[4] www.rumbleseatmusic.com/guitar pic pages/54FenderStrat.html

Another notable solid bodied instrument that helped popularise the electric guitar is the Gibson Les Paul (see Figure 5). Designed by Ted McCarty in collaboration with Jazz Guitarist Les Paul, the instrument was introduced in 1951. Variants on this guitar are still in production today.

Figure 5: Les Paul Guitar[5]

The Fender Telecaster, Fender Stratocaster and the Gibson Les Paul have become regarded as design classics. The underlying concepts behind these guitars have remained constant throughout their existence with minor changes to aesthetics and electrical components. They have become iconic symbols within popular culture as a result of guitarists such as Jimmy Hendrix who have used these

[5] http://www.mylespaul.com/forums/vintage-les-pauls/21011-first-les-paul-burst.html

instruments and pushed their sonic capabilities. The instruments have become symbols that represent both innovation and rebellion against the mainstream. Even non-musicians will recognise and identify such associations with these instruments.

Most current electric guitars still employ the same methods to translate string vibrations into amplified sound. A wide range of pickups exist that enable a broad range of tonal possibilities. There are two main types of magnetic pickups employed today, the single-coil and dual-coil (Humbucker) pickups. The single coil pickup has a magnet that has a coil of copper wire wound around it. The gauge of the copper wire and the number of windings plus the type and strength of the magnet influences the sound of the pickup. Single-coil pickups have a thin, clean, and transparent sound. One of the side effects of a magnetic pickup design is that the coil acts as a very efficient antenna and is susceptible to electro-magnetic radiation from other electrical circuits such as building wiring, computer monitors and fluorescent lighting. This is translated into an audible hum that in recording and performance situations can cause problems. The Humbucker pickup addresses this problem by employing two coils that are each wound in opposing directions and the magnetic polarity for each coil is reversed. This results in the hum being reduced to a negligible level. A Humbucker pickup is said to have a warm rounded tone.

Most electric guitars employ some sort of simple electronic circuit[6] to shape the tone of the instrument. These range from passive filters known as tone controls that use variable resistors to reduce the treble content of the sound, active circuits that allow you to cut or boost predefined frequencies and semi-parametric equalizers that enable you to choose which frequency is cut or boost.

Other methods have been employed that broaden the sonic possibilities through the use of guitar effects[7]. These range from tone controls on guitar amplifiers, reverberation devices, modulation effects such as tremolo and chorus, discreet floor units known as foot pedals such as delays, flangers, distortion and wha -wha pedals that the performer switches on and off using their feet. Some current guitar

[6] http://www.dr-lex.be/guitar/guitarelectronics.html

[7] http://en.wikipedia.org/wiki/Effects_unit

effects units are configured with a multitude of effects (multi-effects units) that include those already mentioned and others such as pitch shifters, ring modulators and filters. Apart from giving the player a selection of effects to choose from they can also combine different types of effects to produce an even wider range of sounds.

The guitar designs and the effects mentioned have existed for decades and have been emulated by many guitar and electronics manufactures since their inception. Most current guitars and effects units closely mimic the sound, feel and aesthetics of the originals. There is also a market for accurate reproductions of vintage guitars, which are sought after and prized by many guitarists of all ages. Also, there are many hardware and software packages that offer emulations of these original instruments, for example, the Roland VG-99 and Native Instruments Guitar Rig.

Guitarists often spend a considerable amount of time trying to recreate the sounds of these classics instruments and the tone quality that famous guitarists like BB King coaxed from their instruments. What was once new and innovative has become the standard to be reproduced and many guitarists will scoff at anything that strays from these ideals both aesthetically and sonically. In his book Electric Guitar & Bass Design, Leonardo Lospennato voices his opinion using the following words:

> Since guitars were electrified, they became a symbol for freedom and rebellion against out-dated rules. But they aren't free and rebellious any more. For fifty years guitars have been wearing the same clothes and have been following the same rules. The former rebel is now itself part of the establishment. [8]

[8] Electric Guitar and Bass Design Leonardo Lospennato www.gitarrendesign.de

Figure 6: A poster showing lack of design changes in electric guitars[9]

Shawn Hammond *Editor in Chief* of the magazine Premier Guitar states that:

> Guitarists as a whole tend to skew fairly conservative when it comes to tones and gear—the majority of electric players insist on using a technology that is utterly and completely antiquated in all other applications (vacuum tubes), our most iconic guitars are half a century old (and counting), and the most extreme tones on 90 percent of our pedal boards were considered "far out" 40 years ago. But no matter how much guitar player's lean toward Luddite, there's no way we're ever going to stop the evolution of the instrument. [10]

[9] Lospennato, L. (2010) *Electric Guitar and Bass design*. Berlin-Germany: LL publishing, p.19

[10] http://www.premierguitar.com/Magazine/Issue/Daily/News/NAMM_2011_Editors_Picks_Day_3.aspx?Page=3

Chapter 1: Innovations

There are some notable artists, guitar builders and electronics manufacturers who have experimented with augmenting the guitar with new technologies and have taken the guitar to new sonic levels. One such example is Roland, a Japanese giant in the manufacturing of music technology and responsible for creating iconic electronic instruments such as the TR 808 and TR 909 drum machines, synthesizers such as the Juno 60, Jupiter 8, SH101 and the TB-303. These classics have helped to shape the sound of popular music and have heavily influenced genres such as Hip Hop, Electro and House music.

Roland has also been a pioneer in the development of guitar synthesisers. In 1978 they introduced the GR500 system. This consisted of a guitar based on the Gibson Les Paul equipped with a hexaphonic pickup and the GR500 synthesiser unit.

A hexaphonic or multi-transducer pickup has a separate output for each string and allows a converter to detect the pitch coming of each string to be translated into note on and note off commands (usually in the MIDI format) that are then passed onto the synthesiser unit. This process allows the user access to the same range of sounds that are produced by hardware and software synthesisers, samplers and many other methods of sound generation that keyboard players enjoy.

There are however, drawbacks with this method of sensing or tracking the string vibrations. The guitarist has to play very accurately and cleanly in order to avoid the false triggering of notes and renders many guitar techniques such as slides and harmonics unusable. Tracking string bends is very difficult and can sound unnatural and again can cause false triggering. Many of the nuances associated with traditional guitar playing are lost. Often, depending on the sounds being used, there can be a loss of dynamic control and as a result the player is forced to adjust their technique to suits the technology.

As a result of these inadequacies, guitar synthesizers have not become widespread in use, especially for live applications. They are however; more useful in recording situations as spurious notes created by the issues with tracking can be corrected in a studio environment.

However, companies such as Industrial Radio[11] have developed bass guitars that try to overcome these problems by splitting each fret into segments for each string, which are wired with resistors. This arrangement detects where you are fretting the string and reportedly improves note detection. I have not been able to test this method personally as I was unable to obtain an example of the instrument. Also, it was beyond the scope of my project in terms of time and budget try the method on my instrument, so I cannot vouch for any improvements the manufacturers claim.

Other MIDI controllers have been developed that try to give MIDI access to the guitarist. Two such companies that have developed guitar based MIDI controllers are Star Labs with a range of products under the name Ztar (see Figure 7), Yamaha with the EZ-EG (see Figure 8) and more recently the Misa Kitara (see Figure 9).

Figure 7: the Ztar[12]

Figure 8: Yamaha EZ-EG[13]

[11] http://www.industrialradio.com.au/products/technology.php

[12] http://www.starrlabs.com/products/ztars/m3

[13] acapella.harmony-central.com/showthread.php?2518108-Starr-labs-Ztar.

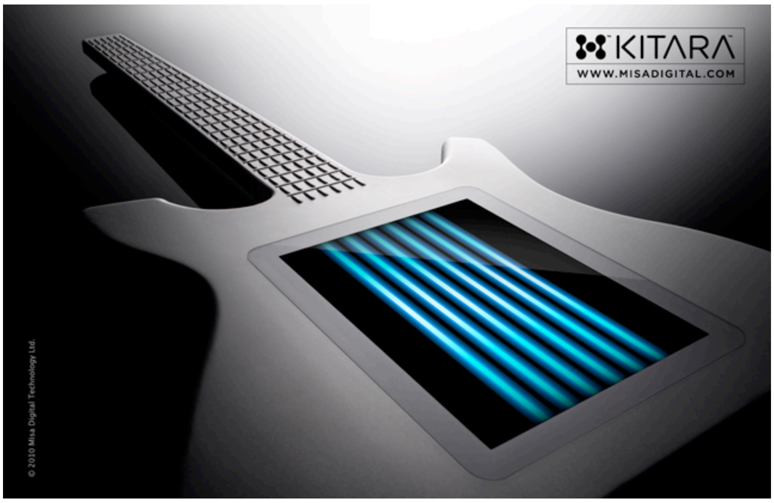

Figure 9: Misa Kitara[14]

These instruments are guitar-like in appearance and as Figures 7, 8 and 9 show. They have a guitar neck that have rows of push buttons laid out in a manner that mimics each note that would be fretted on a conventional guitar. This allows the fretting hand to use the same shapes for chords and fingerings for scales. For the strumming and plucking hand there is a set of strings that do not run up the neck and are not tuned to any particular pitch or note. They are there purely to trigger MIDI sounds. The Misa Kitara uses a touch sensitive screen with a graphical representation of the guitar strings. Because these instruments do not have to sense the vibrations of strings there are no issues with tracking and spurious notes being generated. However, they resemble more the feel and response of MIDI keyboards than they do guitar and as a result none of the nuances such as string bends described earlier are achievable on these instruments.

As a guitarist and percussionist I have long wished to combine the two disciplines and explore new sonic possibilities by developing an instrument and system of playing with solo performance in mind. The concept and origins on my version of the hyper-guitar stem from observing artists such as Preston Reed[15] and Andy McKee[16] who have successfully incorporated percussive techniques into their solo

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[14] http://misadigital.com/index.php?target=gallery&lang=en

[15] http://prestonreed.com/

[16] http://www.andymckee.com/

acoustic guitar playing by striking the body of their guitar with their hands simultaneously playing the strings. However, I wished to take the concept further and utilise electronic percussion sounds alongside physically modelled guitar and synthesised sounds played via the guitar strings and sensors.

On my new instrument, the sensors are placed above and below the strings between the end of the neck and bridge as they pass over the body of the guitar. They are positioned in a manner that allows me to keep my left hand in the correct playing position for strumming and plucking the guitar strings and playing the sensors at the same time. The sensors trigger multi-sampled sounds that are hosted on a suitable hardware or software sampler. Some of the sensors send 'note on' and 'note off ' information to trigger sounds, with other sensors sending controller information. The controller information allows me to make real-time changes to sounds and effects parameters during performance. For example, I am able to change envelope and filter settings on the sampler or increase and decrease decay time in a reverb plug-in.

The guitar is equipped with an hexaphonic pickup (see Figure 10) that has six outputs, one for each string - also referred to as a divided pickup.

Figure 10: Hex Pickup[17]

This is used to drive physically modelled sounds, which are generated by a Roland VG99 Virtual Guitar system (see Figure 11). The VG-99 models both acoustic and electric guitar sounds very accurately, covering most of the major guitar makers. The unit is highly editable and allows the user to build guitar models with alternate tunings and hybrid guitars not possible in the real world. The VG-99 also models

[17] http://www.roland.com/products/en/GK-3/

realistic bass sounds and analogue synthesizers such as the Roland GR 300. The unit also contains physical models of other stringed instruments such as Sitar.

Figure 11: Roland VG-99[18]

Also, the VG-99 has an excellent MIDI implementation that allows the user to control any parameter for example filters, delay times and modulation via controller messages. Examples of how sound patches are created are included in the chapter covering my compositions.

As I am using modelled sounds, I could make compromises in the design of the physical instrument with regards to the choice of woods used which, under normal circumstances would affect the tone of the guitar. I did however, have to pay attention to the attack and sustain characteristics when choosing the materials.

1.1 Electronic Drum Kits

When approaching the design of my hyper-guitar I knew I wanted to include trigger pads as controllers. I initially started by researching how electronic drum triggers work. An electronic drum kit consists of drum pads (triggers) that are struck with sticks or hands. A drum trigger converts energy when struck into electrical impulses. The impulses are then fed to a drum module also known as a drum brain, which converts the impulses into MIDI information, which in turn triggers a drum sound or sample. There are two main types of sensors used by electronic drums manufacturers. Piezo Electric Transducers also known as Piezo pickups and Force Sensitive Resistors referred to as FSR's.

[18] http://www.roland.com/products/en/VG-99/

1.2 Piezo Electric Transducers

The most common method for sensing drum strikes used by manufacturers of electronic drum kits is through the implementation of piezo electric transducers (see Figure 12).

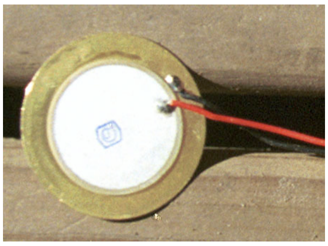

Figure: 12 piezo pick-up

Piezo pickups have a very defined transient and they work by converting vibrations into electrical voltage.

> The piezoelectric transducers work on the principle of piezoelectric effect. When mechanical stress or forces are applied to some materials along certain planes, they produce electric voltage. The voltage output obtained from the materials due to piezoelectric effect is very small and it has high impedance. To measure the output some amplifiers and auxiliary circuit are required. [19]

Piezo pickups are very responsive; they have a fast attack and are capable of detecting rapid hits on the drum trigger extremely accurately. However, piezo pick-ups have a swift decay of the voltage even if you apply continued pressure to the pickup after the initial strike. As the decay is short you cannot sustain the sound being triggered, i.e. it is not possible to play legato notes using this method of detection.

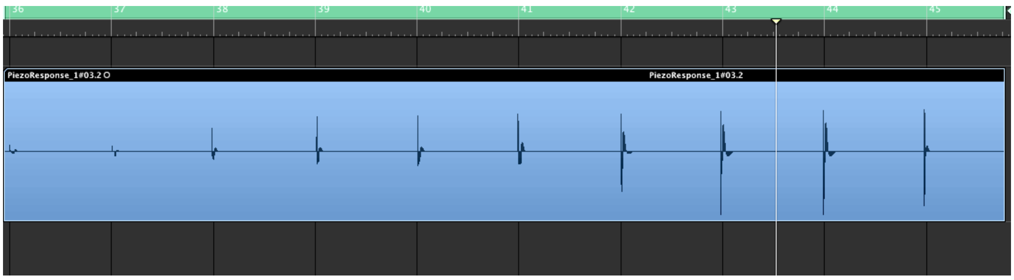

Figure 13: Piezo Pick-up response (screen shot)

[19] www.brighthub.com/engineering/mechanical/articles/52190.aspx

Figure 13 is a recording I made in Logic Pro 9 of a piezo pickup being struck. Note the sharp transients and rapid decay in the waveform. Also, there is an increase in amplitude the harder the piezo is struck which can be translated into velocity information for drum triggering.

As the voltage output from a piezo is small, I put the pickup through a microphone preamp first to increase the gain in order to bring the signal up to line level.

1.3 Piezo drum pad construction

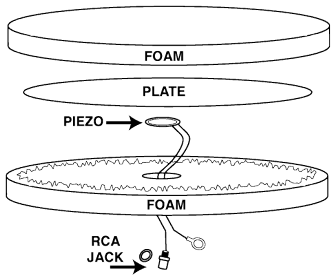

Figure 14: Piezo Drum Construction [20]

Figure 14 illustrates how a typical Piezo drum pad is constructed. The Piezo is attached to a metal plate and sandwiched between two pieces of foam. The foam is essential when constructing piezo drum triggers as piezo pickups work by detecting vibrations. The foam is used to isolate the piezo and stop it from being triggered by vibrations when other pads on the drum kit are struck.

2.4 Force sensitive Resistors

The second types of sensors used in electronic drum manufacture are Force Sensitive Resistors (see Figure 15). These are used to sense pressure and force and do not detect vibrations.

[20] http://www.electronicdrums.com/pads/pads2.htm

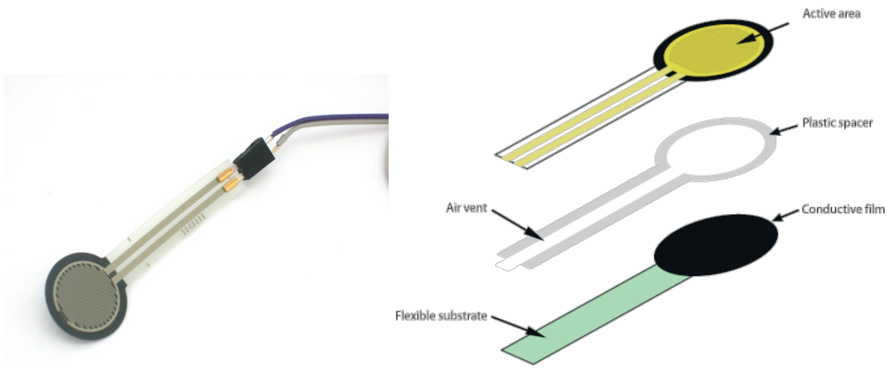

Figure 15: Interlink 402 FSR[21]

> Force Sensing Resistors (FSR) are a polymer thick film (PTF) device, which exhibits a decrease in resistance with an increase in the force applied to the active surface. Its force sensitivity is optimized for use in human touch control of electronic devices.[22].

Figure 16 presents a graph that illustrates FSR resistance with the vertical axis showing resistance in Ohms and the horizontal axis displaying force. From the graph it is clear that there is maximum resistance when there is no force applied. This results in no voltage passing through the circuit. The resistance decreases in relation to how much pressure is applied and allows an amount of voltage to pass through relative to how much force is applied. This will allow for drum samples to respond to velocity. The sensor will also continue to allow voltage through for as long as pressure is applied to it. This means that sustained notes are possible with FSR sensors.

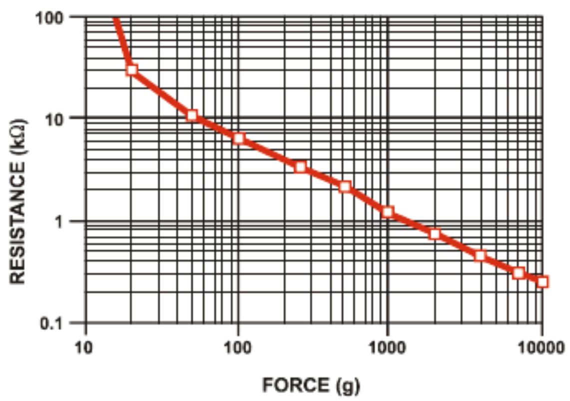

Figure 16: FSR Sensitivity[23]

[21] http://sensorwiki.org/doku.php/sensors/force-sensitive_resistor

[22] Source, Interlink Electronics, FSR Integration Guide www.interlinklelectronics.com

2 Guitar Design and Concept.

2.1 Ergonomics

> Historically successful models are not necessarily perfect. Take advantage of the lessons they offer, but be open to find new paths. Les Pauls and Stratocasters are considered "traditional" today, but when they were created, they were radical examples of innovation themselves. [24]

The design of the electric guitar has remained pretty constant since its inception. It can be argued that some traditional aspects of the guitar's design are ergonomically flawed. Conventional designs do not promote the best playing positions that encourage good posture and comfort whilst performing. Many guitars force the user into awkward positions with regards to the left and right arms and hands. This can often result in repetitive strain injuries. RSI injuries are common amongst musicians and can be debilitating and in severe cases render the musician unable to play for long periods of time or permanently.

An RSI injury that affects guitarists in particular is known as Carpel Tunnel Syndrome (CTS). This injury relates to the way in which the wrist is bent and on the type of stresses it is subjected to whilst playing the guitar.

A team of ergonomics researchers, from the University of California at San Francisco and McMaster University in Ontario, Canada have carried out research into the effects and causes of CTS, the findings show that,

The research team studied the pressure that is placed on the nerve in the carpal tunnel in various wrist postures in 37 healthy men and women between the ages of 22 and 50. Wrist postures that are not neutral (that is, bent or flexed) cause increased pressure on the nerve. The researchers concluded that when sustained pressure on the carpal tunnel reaches 30 mmHG, injury is likely to occur.

In order to keep pressure below 30 mmHG, it is recommended that sustained wrist extension (bending the hand back) should not exceed 32.7 degrees, wrist flexion (bending the wrist toward the palm) should not

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[23] Source, Interlink Electronics, FSR Integration Guide www.interlinklelectronics.com

[24] Lospennato, L. (2010) *Electric Guitar and Bass design*. Berlin-Germany: LL publishing, p.19

exceed 48.6 degrees, ulnar deviation (sideways toward the small finger) should not exceed 14.5 degrees, and radial deviation (sideways toward the thumb) should not exceed 21.8 degrees.[25]

The diagram below (see Figure 17) demonstrates that the common design of guitars forces the player into awkward positions, the dark dots show where stress points can occur.

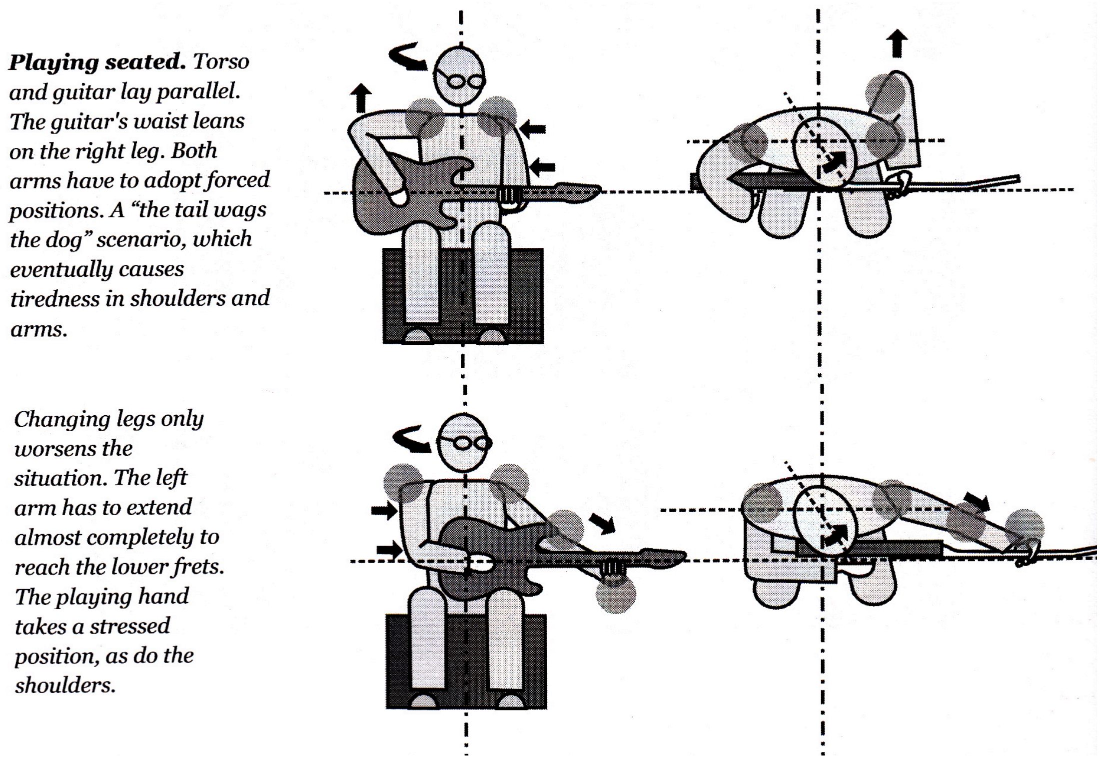

Figure 17: Awkward playing positions[26]

This diagram below (see Figure 18) illustrates a position that will promote good posture and positioning of left and right hands. This position will also help to alleviate tension that may occur in other parts of the body. Please note that with conventionally designed guitars it is almost impossible to achieve this position because the rear bout of the guitar, which is resting on the right leg, gets in the way and will not facilitate an adequate positioning of the guitar.

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[25] http://ergonomenon.com/ergonomics-articles/ergonomics-research-findings-could-help-prevent-carpal-tunnel-syndrome/

[26] Lospennato, L. (2010) *Electric Guitar and Bass design*. Berlin-Germany: LL publishing, p.69

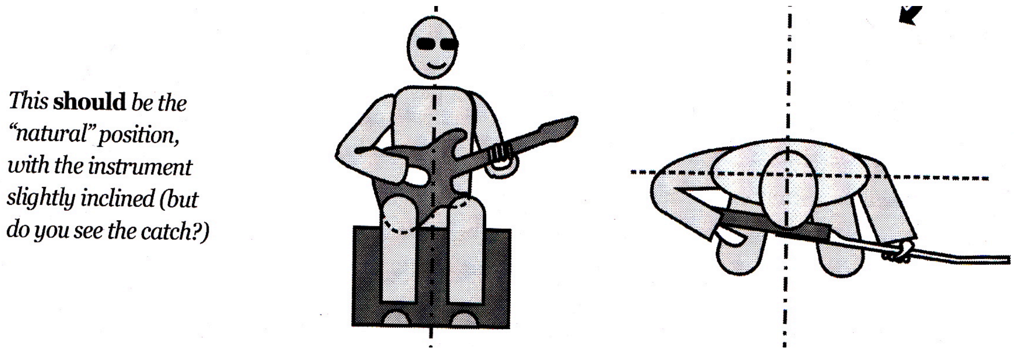


Figure 18: problem with rear bout of conventional guitars.[27]

The picture below (see Figure 19) is a Klein guitar that has been designed with ergonomics in mind.

Figure 19: Klein guitar[28]

This guitar performs exceptionally well form an ergonomic perspective and has a small but loyal following of player. The original Klein guitar is no longer available for purchase but there are copies made by other manufacturers and custom builders available. One of the reasons that this guitar has not been more widely take up is due to the conservatism that exists amongst guitar players with regards to the body shape of the guitar. As the Klein guitar does not conform to the normal shape of the Gibson Les Paul's and Fender Stratocasters, it never became popular

[27] Lospennato, L. (2010) *Electric Guitar and Bass design*. Berlin-Germany: LL publishing, p.69

[28] http://www.edroman.com/guitars/klein.htm

as the designer hoped it would. It is with this in mind that I decided to build a guitar that accommodates all the ergonomic considerations as well as hopefully being aesthetically pleasing to the guitar playing community at large. Also included on the guitar are a series of trigger pads for the right hand-placed just above and below the strings. The main considerations in designing an ergonomic guitar are as follows.

- Balance
- Weight
- Playing effort

Balance.

Traditional design dictates that there is a headstock at the end of the neck .The headstock houses the guitars tuning mechanisms. The headstock, combined with the weight of the tuners can result in a poorly balanced instrument with a tendency for the neck to dive towards the floor. This means the player has to use their fretting hand to support the weight of the neck and thus creating tension in the arm, wrist and shoulders.

Weight.

It is commonly believed that the heavier the guitar the better it will sound in terms of tone and sustain. The Gibson Les Paul is infamous as being an extremely heavy guitar and it is this factor that is said to define its deep tone and long sustain. However through using different construction methods and selection of woods similar sustain and tone can be achieved with a much lighter instrument.

Playing effort.

Reducing the effort it takes to play the guitar can greatly enhance the experience and increase efficiency. Weight and balance contribute to the efficiency, but also more importantly the position of the fretting hand is a major factor in reducing the strain on the hand and wrist.

In the next chapter I shall describe in detail how I came to the design of the final prototype guitar, and the construction of the instrument by guitar Luthier, Paul

Cuthbert. I shall also detail the first two prototypes that I made which informed my design of the of the prototype guitar three. The first of which explored the use of piezo sensors that were placed on an old guitar. The second guitar was one that I constructed from commercially available guitar parts, i.e. neck, body and hardware that I purchased and put together. This second instrument was used as a test bed for Force Sensitive Resistors to act as sensors. With these two instruments I used two designs that are extremely common i.e. Gibson Les Paul shape and a Fender Telecaster shape. I wished to compare the two shapes ergonomically, and to assess their strengths and weaknesses. I also used the two designs in order to weigh up any ergonomic enhancements I might need to make.

2.2 Prototype Guitar 1

My first experiment with implementing triggers on a guitar (see Figures 20 and 21) consisted of attaching six piezo pickups onto a Gibson Les Paul shaped guitar, which were fed to an Alesis Trigger I/O (see Figure 22) in order to convert the impulses into MIDI information. The MIDI output was then fed into a computer to trigger drum samples. As piezo pickups respond to vibrations there is a problem with cross talk between individual pickups. As a result some method of isolating each pickup and preventing the piezo's from picking up vibrations from the guitar body had to be implemented in order to minimise false triggering. Figures 23 and 24 illustrate my attempt at isolating each pickup from the guitar and each other. I used a silicone washer and an acoustical decoupling material, which yielded good results and prevented false triggering. However, Figure 25 illustrates that the sensors with the vibration isolation take up more space and reduces the number of drum pads that can be placed on the guitar body.

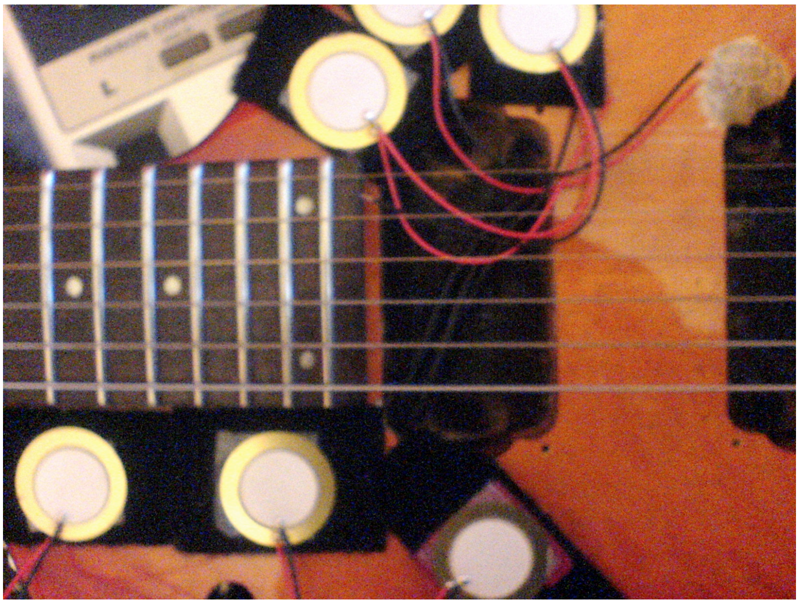


Figure 20: placement of piezo pickups

Figure: 21 installing piezo pick-ups

Figure: 22 Alesis Trigger I/O[29]

[29] http://www.alesis.com/triggerio

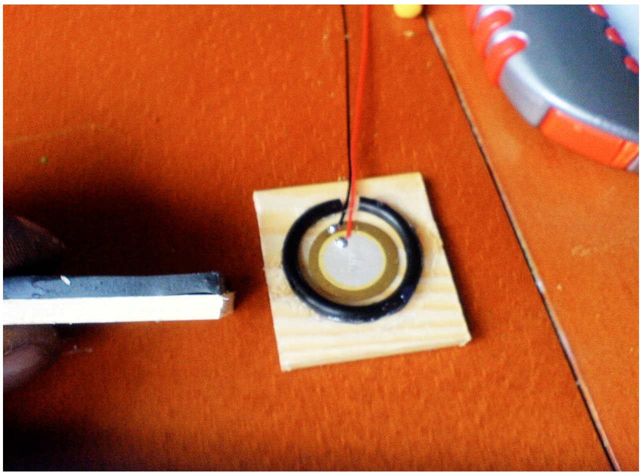


Figure 23: acoustic isolation

Figure 24: finished sensor

Figure: 25 sensors installed on prototype 1

The piezo sensors on this instrument worked successfully and I was able to send trigger information efficiently to the Alesis trigger finger, which in turn converted the impulses into MIDI, information that was then sent to the computer for the triggering of drum sounds.

However, as piezo pickups only produce short transients, it is not possible to send sustained notes to the computer. As I wanted to play instruments sounds other than drum sounds that require longer note messages, the piezo pickups proved to be unsuitable for the project.

Also, due to the need for the acoustic decoupling between the sensor and guitar body, I found that the sensors were too far apart for a practical and efficient playing technique. This resulted in the fingers of the striking hand having to span to large a distance between each sensor making it ergonomically undesirable. This exercise however, allowed me to try the concept out quickly and cheaply. It enabled me to get a sense of how it would feel to have sensors positioned in the way that I had envisaged and to start experimenting with playing methods.

2.3 Prototype Guitar 2

I constructed the second instrument from guitar parts that are based on the Fender Telecaster guitar (see Figure 26). I also used a Tom Scarff, Miduino 16–way MIDI sensor board (see Figure 27), which comes in kit form to convert the signals from the force sensitive resistors into MIDI information. The Miduino utilises an Arduino board, which includes a preprogrammed Atemga microcontroller.

Figure 26: Prototype Guitar 2

The Arduino board is an open source physical computing platform based on a simple input/output board and a development environment (see Figure 28) that allows you to write code also known as a sketch and upload it to the I/O board. The Tom Scarff board already has the necessary code written for it. This is simply loaded onto the board using the Arduino development environment. It is possible to reassign MIDI note numbers and adjust velocity sensitivity by altering the script.

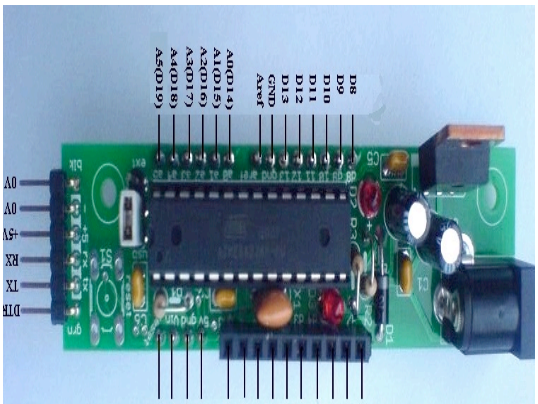


Figure 27: Miduino board[30]

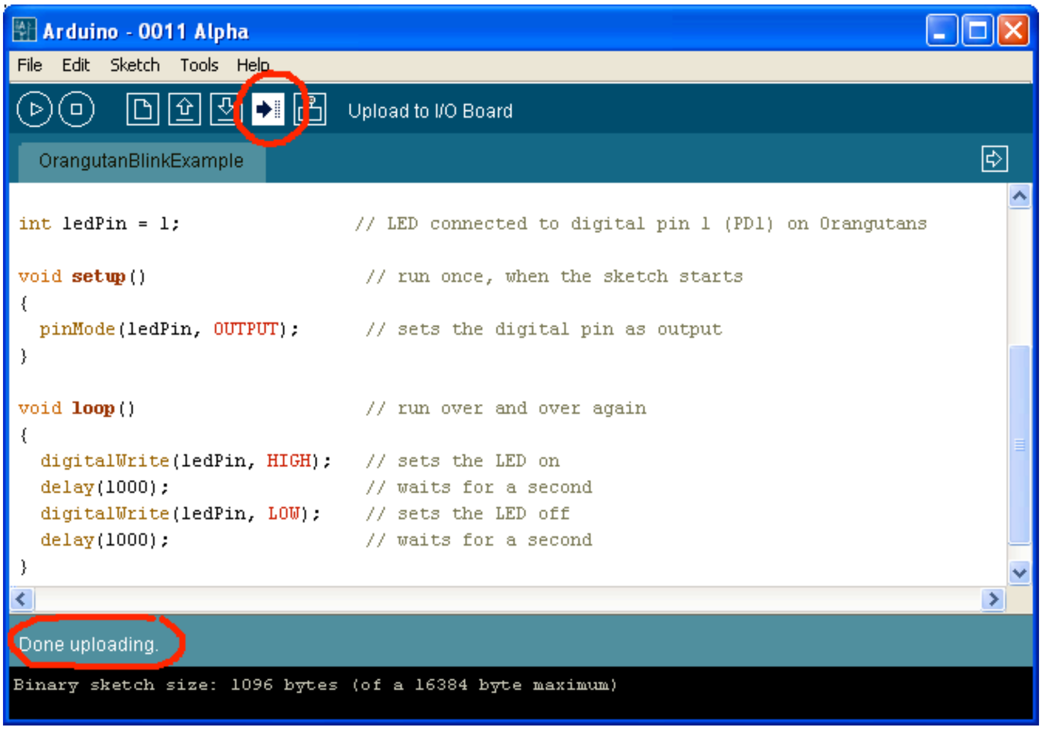


Figure 28: Miduino Script [31]

The positioning of the sensors was much better on this instrument than on the first prototype. The smaller diameter of the FSR sensors and the fact that FSRs do not require any form of acoustic isolation meant that they could be placed closer together and arranged in a more ergonomic fashion. This facilitated an easier and a

[30] http://tomscarff.110mb.com/midi_boarduino/midi_boarduino_PINS_wiring.jpg

[31] http://www.pololu.com/docs/0J17/all

more efficient usage of the triggers. The FSR sensors also allowed me to hold a note thus enabling me to play legato lines.

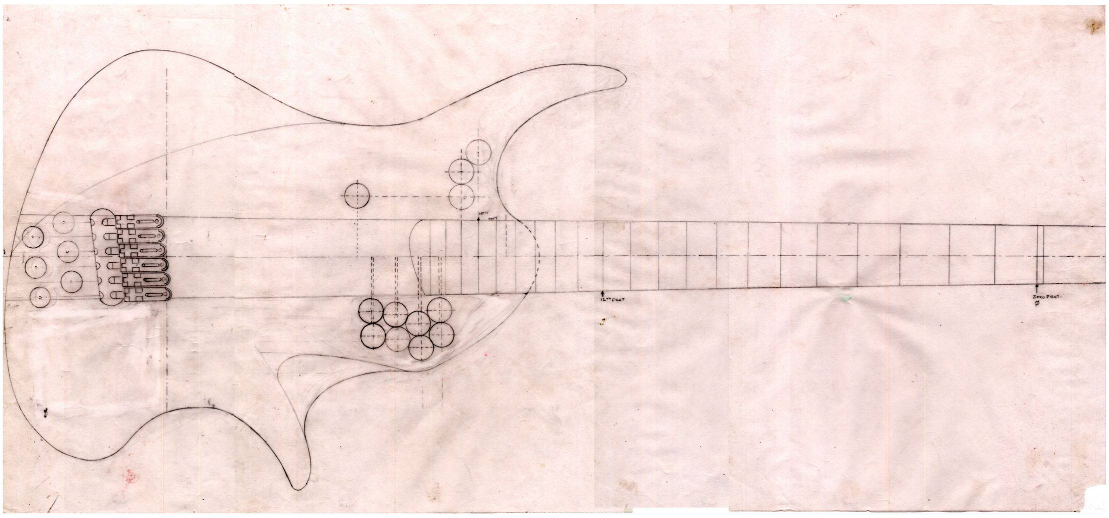
Although I was able to successfully trigger sounds on both prototypes, a problem common to both was finding the optimal playing position that allowed me to strum and pluck the strings and play the sensors at the same time. With prototype 1, the Gibson Les Paul shape, I found my strumming hand was at an awkward angle, which caused fatigue very quickly. While prototype 2, the Fender Telecaster shape was much better, the neck of the instrument was heavy, which meant I had to support the weight of the neck with my fretting hand, and again this caused fatigue mainly in the wrist and elbow, again making it awkward playing the instrument for any length of time.

These two prototypes gave me a good understanding of improvements that would have to be made in terms of body shape and balance of the instrument and positioning of sensors. Also, with the Miduino board, programming which note numbers was assigned to each sensor was awkward and time-consuming. It is with these findings that I set out to design prototype guitar 3.

2.4 Prototype Guitar 3

Figure 29: prototype guitar 3

I started off with a number of sketches, which resulted in a full-scale drawing of the instrument (see Figure 29a). The design is loosely based on the Fender Stratocaster with adjustments made to the rear bout of the guitar, the lower horn and an extended upper horn. I also incorporated into the design a headless neck with the tuning mechanisms at the rear of the guitar body thus alleviating the need for a headstock resulting in a reduction of weight at the end of the neck.



Fi
gure 29a: scale drawing

The guitar body is designed so that it allows the instrument to be positioned in a way that enables the correct posture required for efficient performance. The rear is specifically shaped (see Figure 29b) so that the issue illustrated in figure 30 is no longer a problem as the guitar sits comfortably between the legs (see Figure 29c). The guitar also has a supporting feature in the form of a curved lower horn that sits on the left leg for a right-handed player. This feature ensures that the neck is angled upwards which means the fretting hand is no longer supporting the weight of the neck and encourages the hand to be in a more comfortable position thus reducing the effort it takes to play the instrument (see Figure 31). The extended upper horn sits comfortably against the chest and helps to support the balance of the guitar further; this feature also stops the guitar from moving. The design is primarily intended for seated playing but it is also be suitable for playing in a standing position.

Figure: 29b Rear bout Figure: 29c rear

bout positioned

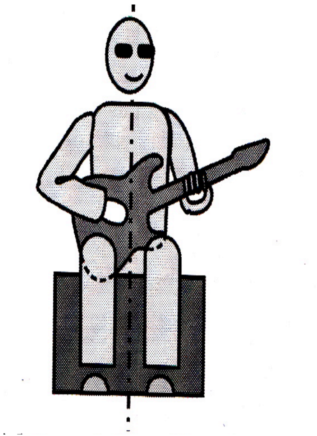


Figure: 30 Guitar body design flaw[32] Figure: 31 Testing new designs

[32] Lospennato, L. (2010) *Electric Guitar and Bass design*. Berlin-Germany: LL publishing, p.69

3 Guitar build.

Paul Cuthbert, a Luthier based in Manchester constructed the guitar using my full scale drawing and added his expertise to improve aspects of the design. Cuthbert included a contoured neck body joint, a compensated nut that aids in improving intonation and bearings that are placed under the bridge that stop the strings from sticking and improves tuning stability.

Cuthbert also advised me on the types of wood to use, for example, the core of the body is made from Swamp Ash. Swamp Ash is light in weight and resonates well across all frequencies and also transfers transients from the guitar strings extremely well, giving the guitar a very percussive attack. This is a feature I specified for the guitar as I wish to play in play a percussive style. The neck is constructed from three pieces of Curly Maple. The central piece of Maple has the grain running in the opposite direction to the two pieces sandwiching it. This gives the neck greater strength and stability. The fretboard and the top of the body are made from Wenge. This was chosen purely for aesthetic reasons.

Through Neck Design.

The guitar design features a through neck, which means that the wood used for the construction of the neck runs the whole length of the body of the guitar (see Figure 32).

Figure: 32 Guitar neck construction

Having a through neck guitar design gives the instrument stability and forms the core of the body. This feature aids in increasing sustain resulting from the strings being attached to the same piece of wood as the fret board, bridge and the nut. This also allows the guitar to stay in tune longer.

Having a through neck also means that there is no heel on the back of the guitar as is the case on a traditional bolt on set necks where the neck is joined to the body of the guitar. This means that area where the neck and body meet can be contoured (see Figure 33) which allows better access to the upper frets and in the case of this instrument the sensors.

Figure: 33 Neck heel joint

3.1 Guitar hardware

The nut on the guitar is of the compensated type. The intonation on different parts of the guitar can vary. This can cause a guitar to sound out of tune in various parts of the neck when playing chords. It is a problem common to all guitars and other fretted stringed instrument as they use equal temperament tuning. This is caused by the fact that each string has a different diameter but are all of the same length. This effect is not noticed on instruments such as pianos as each string is of a different length and intonated accordingly.

> The guitar is fretted to produce musical notes in a scale called **equal temperament**. **Equal temperament** means that the 12 notes within each octave are evenly spaced. Well, not exactly - the frets are placed closer together as the notes get higher, such that the frequency doubles in

the span of an octave. But this happens evenly - each fret space is .94387 as wide as the previous fret space, as you go up the fret board.

The **auditory perception** is that the notes **sound evenly spaced**. There is no inherent problem with intonation due to the fret board in design. Intonation problems are primarily

the result of the additional tension created from the strings being fretted, and other effects. These need to be compensated for **at both ends** of the strings.

If we compensate at the bridge, but not at the nut, then notes around the 12th fret will be in tune with the open strings, but notes nearer to the nut will be sharp.[33]

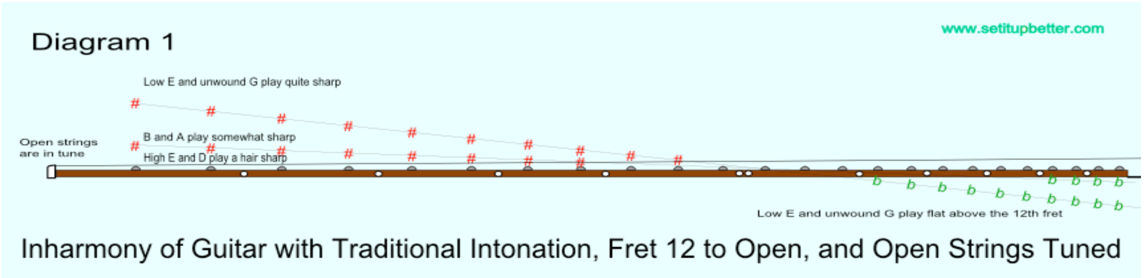


Figure: 34 Traditional intonation[34]

The diagram above illustrates how the intonation changes on different parts of the neck.

Most commercially available guitars do not have a compensated nut. This is due to a lack of understanding and the perceived cost of applying such a system.

Because each string is of a different diameter when fretted they stretch at a different rate, which means they go sharp at a different rate relative to each other. This results in the guitar playing slightly out of tune on different parts of the neck. A compensated nut slightly changes the scale length for each string taking the diameter of the string into account. (See Figure 35)

[33] http://www.setitupbetter.com/Geometry-and-Intonation.php

[34] http://www.setitupbetter.com/Geometry-and-Intonation.php

Figure: 35 compensated nut

3.2 Guitar Bridge

The guitar is fitted with a Hannes Bridge (Figure 36), which is a unique design as each string saddle individually sits on the guitar top. Each saddle has a greater contact area with the guitar surface than most traditionally designed bridges; this insures string vibration is transferred to the guitar body as efficiently as possible. Each saddle is also isolated from each other with the result being that individual strings do not transfer vibrations to adjacent strings. This results in an increase in note separation between strings, which in turn makes individual notes within a chord easier to distinguish from each other.

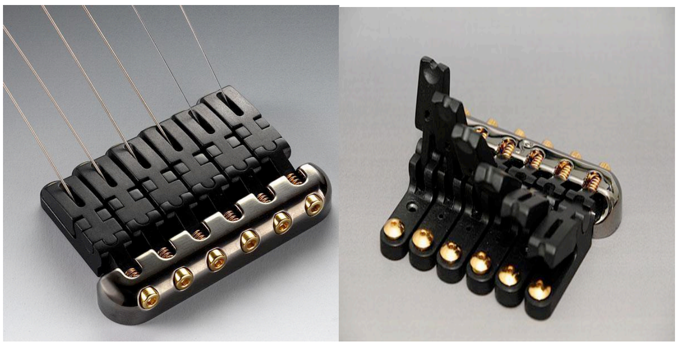


Figure: 36 Hannes Bridge[35]

3.3 Guitar tuners

[35] http://schaller-electronic.com/hp159464/Schaller-Flyer-Hannes-Bridge.htm

Steinberger gearless tuners (see Figure 37) are used to tune the strings. The tuners have no gears, and have a 40:1 tuning ratio, which makes them extremely accurate and reliable. I specifically chose these tuners, as they are the easiest to adapt for headless guitar design. There are guitar tuners available commercially specifically for headless guitars, however they are extremely expensive and are not readily available.

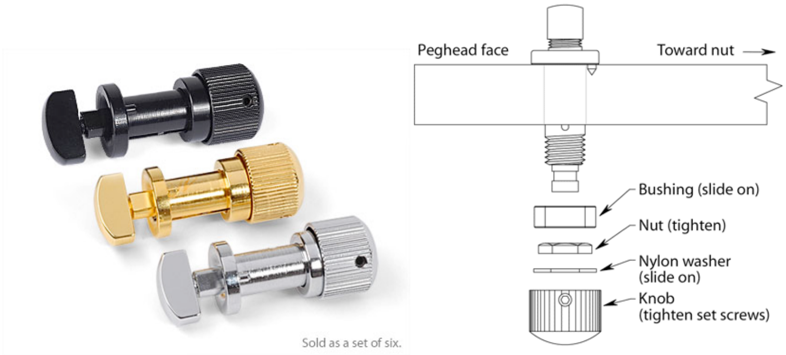


Figure: 37 Steinberger tuners[36]

The strings pass over the bridge saddles, through the body and are then passed over bearings (see Figure 38) that ease their flow and aids in easier tuning.

Figure: 38 Bearings

Without the bearings it would be extremely difficult to bring the strings to the correct pitch, because, as you increase the tension on the strings they tighten against the surface they are resting on which results in them becoming extremely

[36] http://www.stewmac.com/shop/Tuners/Guitar,_solid_peghead_tuners/Steinberger_Gearless_Tuners.html?tab=Pictures#details

difficult to tighten after a certain point. Paul Cuthbert used his ingenuity and employed the use of bearings from skateboard wheels to overcome this problem.

3.4 Guitar Electronics

For the triggers I have used force sensitive resistors and an Eowave Eobody2 OEM analogue/digital USB converter (see Figure 39) that has 29 digital I/O and 16 analogue inputs. This unit allows the connection of sensors directly to a computer through a high–speed USB connection. The Eobody2 is powered via the USB input and therefore negates the need for batteries or an external power supply. The board comes with a software editor (see Figure 40), with which you program each sensor input. Each input can be assigned to send one of the following:

- MIDI note messages
- Control change messages
- Program change
- Channel after touch
- Pitch bend

The ability to program the board easily was one of the main considerations in choosing to use the Eobody2.

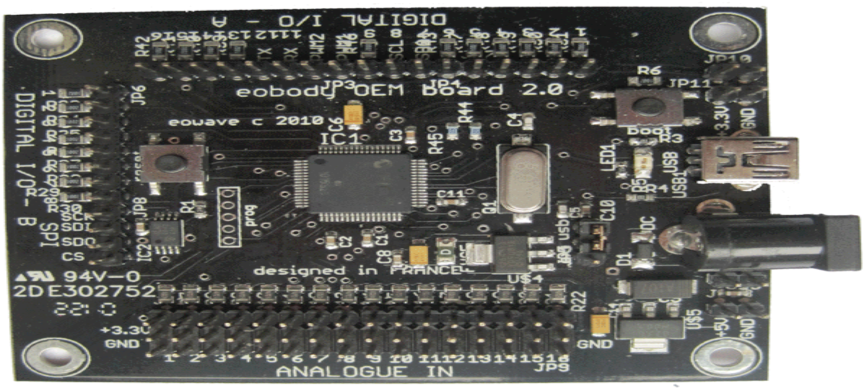


Figure: 39 Eobody2[37]

[37] http://www.eowave.com/products.php?prod=67

Figure: 40 Eobody editor (screen shot)

3.5 Sensor installation

It was through experimentation and trial and error that I found the optimum positions for the sensors. I cut out a full-scale version of the guitar using foam board in order to try different positions for the sensors (Figure 41). They have been placed in a fashion that allows me to play both the strings and the sensors efficiently with minimal effort and movement. Figure 42 is the Eobody2 installed in the guitar with the sensors wired into it and Figure 43 shows the sensors in place.

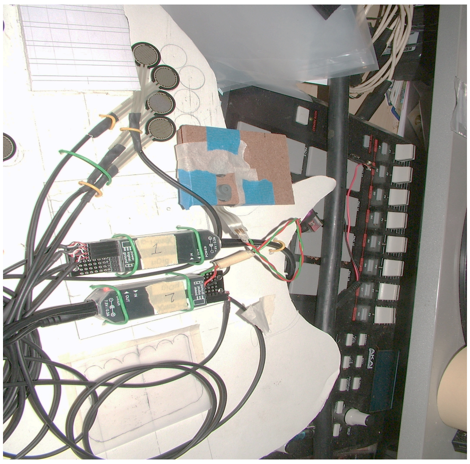


Figure: 41 Testing positions of sensors

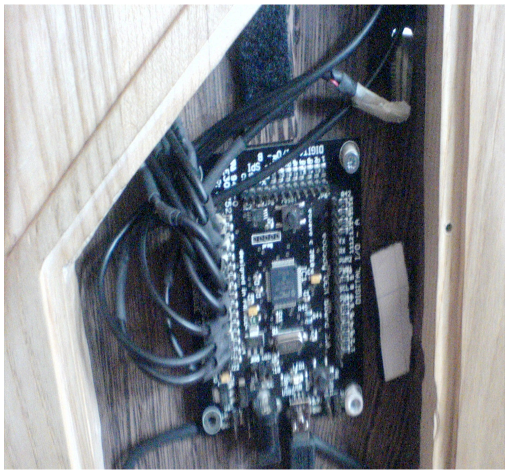


Figure: 42 Eobody Installed

Figure: 43 sensors in place

The final piece of electronics to be installed on the guitar is the Roland GK–3 pickup (see Figure 44). Figures 45 and 46 show the pickups electronics installed. This is a pickup known as a hex pickup that senses each individual string the outputs them individually and in this case to be used with the Roland VG-99 physical modeling guitar processor. The Roland VG–99 can be programmed to emulate the sound of many different types of guitars including electrics, bases, acoustic guitars, and other instruments such as sitars and mandolins. The VG-99 can also be programmed to sound like synthesisers and is ideal for creating synth bass sounds etc.

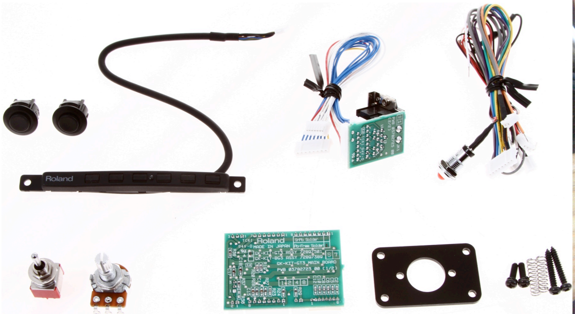


Figure: 44 GK 3 Kit[38]

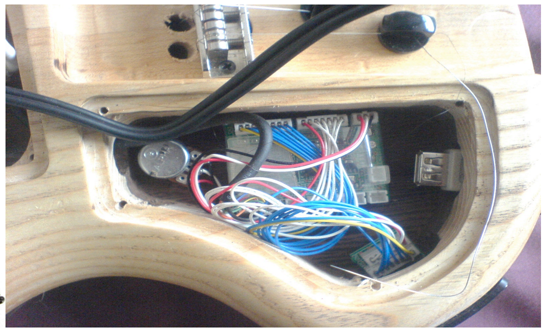


Figure: 45 GK 3 Kit installed

Figure: 46 GK3 pickup installed

In the next chapter I will detail how each of the electronic elements are combined and used. I shall also show how the guitar and the VG-99 are integrated with a computer and the music software used to generate sounds. These descriptions will be placed in context within a composition that illustrates the diverse range of textures and sonic capabilities that can be produced with this instrument.

[38] http://www.sweetwater.com/store/detail/GKKITGT3

4 Composition: *Homespun*

4.1 Overview of composition.

The purpose of the composition is to explore the sonic and control capabilities of the Mistry-hyper guitar and to start to establish a body of work for the new instrument. It also performs the function of creating a new work to practice on the instrument that utilizes the many new techniques and performance methods that I have had to develop. Also, I have experimented with combining software and hardware in order to create the sounds that are used within the composition. The aim was to create a diverse palette of sounds and textures that allow me to explore harmony, melody and rhythm on the instrument.

I have chosen to use the Indian Raag Lalit for this composition. A Raga is a scale or mode used in Indian classical and folk music and each Raag usually has a set of rules that defines its character and purpose of use. Many Ragas actually share the same notes but it is the ascending and descending order in which they are played in and also the inflections applied in the performance that determine its character. Also, certain notes are emphasised which further aid in characterising a specific Raag.

> Broadly speaking then, a raga can be regarded as a tonal framework for composition and improvisation; a dynamic musical entity with a unique form, embodying a unique musical idea. As well as the fixed scale, there are features particular to each raga such as the order and hierarchy of its tones, their manner of Intonation and ornamentation, their reflective strength and duration, and specific approach. Where ragas have identical scales, they are differentiated by virtue of these musical characteristics.[39]

4.2 Raag Lalit

In Indian classical music tradition Ragas generally have a specific time of day in which they are performed. Raag Lalit is a predawn Raga and is described as having

[39] Rao, S., Meer, W., Harvey, J. (1999) *The Raga Guide.* UK: Nimbus Communications International Limited, p.1

serene and meditative qualities. As with many Indian Ragas, Lalit utilises different notes when played ascending (Arohi) and descending (Avarohi).

Figure: 47 Raag Lalit[40]

Witnessing my parents meditate at this time of day for as long as I can remember is the inspiration behind using this particular Raag.

There are many rules that govern the performance of an Indian Raag. For certain Raags, these can be extremely complex and it can take many years to master the nuances of a particular Raag. As I have not studied Indian classical music, I am using Lalit as inspiration and as a starting point for my composition – as a musical symbol for my parents. I have tried to emulate the feel and mood through listening to examples of Lalit being performed by exponents of the genre. Thus, this composition is not an accurate representation of this style of music, but rather a personal interpretation.

Another aspect of Indian classical music is that it is traditionally an improvised form but one which follows a specific structure. Each piece will contain certain sections as listed below.

- **Alap**: The introduction, known as the Alap begins a recital and is an exploration of the notes contained within the Raag and has no fixed time signature or rhythm.
- **Jor**; The Jor introduces the basic themes and develops melodic phrases. Both the Alap and Jor are performed without any percussive accompaniment.

[40] http://www.ancient-future.com/serenade.html

- **Gat**: The theme of the performance is further developed by the introduction of a percussive element, usually Tabla, which consists of two drums. A low-pitched drum called Bayan and a higher pitched drum Dayan.

Figure: 48 Tabla.[41]

I have loosely followed the above convention for the structure of my composition, but again it is an interpretation of the style in a contemporary musical language that reflects both my Indian and Western heritage.

I have also included a style of Indian classical percussion known as Tabla Tarang. Tabla Tarang is a form of tuned percussion whereby a number of Dayans are arranged around the performer and each drum is tuned to a specific pitch of the Raag being performed. A Tabla player usually accompanies the Tarang artist. I have included the Tarang in the first half of the Gat section.

[41] http://chandrakantha.com/articles/indian_music/tabla.html

Figure: 49 Tabla Tarang.[42]

In the next part I will examine some of the recording and sound design techniques that I have used during the production of the piece.

4.3 Equipment/software used

Software

- Logic Pro 9
- Ableton Live
- Samplit
- Kontakt sampler
- Izotope Stutter Edit and various audio plugins

Hardware

- Roland VG-99 Guitar system

4.4 *Homespun*

The composition is entitled *Homespun* as the final section of the piece is inspired by a campaign that Gandhi initiated in 1920 during the Indian independence struggle. Homespun was a protest against British colonial rule and specifically to bring light to the fact that cotton grown in India was being exported to the UK and being spun into yarn/woven into cloth and then sold back to the Indians at inflated rates. Traditionally in India, cotton was always spun in the villages and supported local economies. This industrialisation of cotton left many Indians unemployed and driven into poverty. Homespun was a drive to encourage Indians to become economically independent of the British Raj and was a direct attack on the Lancashire cotton industry. The effect of the campaign on the mill workers in Lancashire was to create unemployment and hardship as the mill owners compensated their losses by penalising their employees. In 1931 Gandhi was invited to visit a mill in Darwen, Lancashire by various Mill owners, to see for himself the effect his campaign was having. Local mill workers greeted Ghandi with

[42] http://www.discogs.com/Pandit-Kamalesh-Maitra-Trilok-Gurtu-Tabla-Tarang-Melody-On-Drums/release/1193353

great affection. They made it known to him that they understood it was not India that was creating hardship for them, but rather that the actions of unscrupulous mill owners were responsible for creating unemployment and poverty.

The composition *Homespun* is dedicated to my father as, ironically, when he first came to the UK from India in 1956, he landed in a small mill town in the north of England called Stalybridge. Stalybridge has had a long history of cotton production and he found employment in one of its cotton mills.

As stated earlier, I have drawn influence for my composition from an Indian classical tradition. I have however, used it only as a starting point to explore new possibilities with the hyper-guitar I have created. The rules that govern Indian classical music performance and composition have been taken as a point of departure for my own work. *Homespun* is not only an exploration of the notes of the Raag Lalit but also an exploration of production techniques, sound design and new playing techniques. I have experimented with creating ambient sounds using delays, filters, stutter effects and other audio processing techniques, some of which I will be describing in the next section. For recording and sound creation I have mainly used two pieces of software Logic Pro 9 and Ableton Live. Ableton Live has been used to create some of the ambient pad sounds that are prevalent throughout the piece.

The Roland VG-99 has been used for the guitar sounds and as it is a physical modeling device, it is possible to create sounds and tunings for the guitar and store them with in the unit. The tuning used for the entire recording is as follows from Top E string to bottom E string.

- Db
- Ab
- F
- Db
- Ab
- Db

4.5 Sound design

The introduction to the piece starts with the gentle sound of water and birds in order to create an ambient texture representative of the village in which my parents lived and meditated early in the morning. The sound of water reappears throughout the piece and is there to represent journey and passage of time. Also water plays an important factor in where cotton mills exist. One of the reasons why the cotton industry grew in the North West and in particular Lancashire is that it is a soft water area, as soft water is better suited for cotton production. This is followed by slowly introducing the guitar, which is used to create an ambient pad sound. This is achieved by using a volume pedal that slowly brings in the sound of the guitar. The guitar is passed through a delay set to quarter notes with feedback. By swelling the guitar into the delay the effect of long sustained notes is created and thus creating a pad sound.

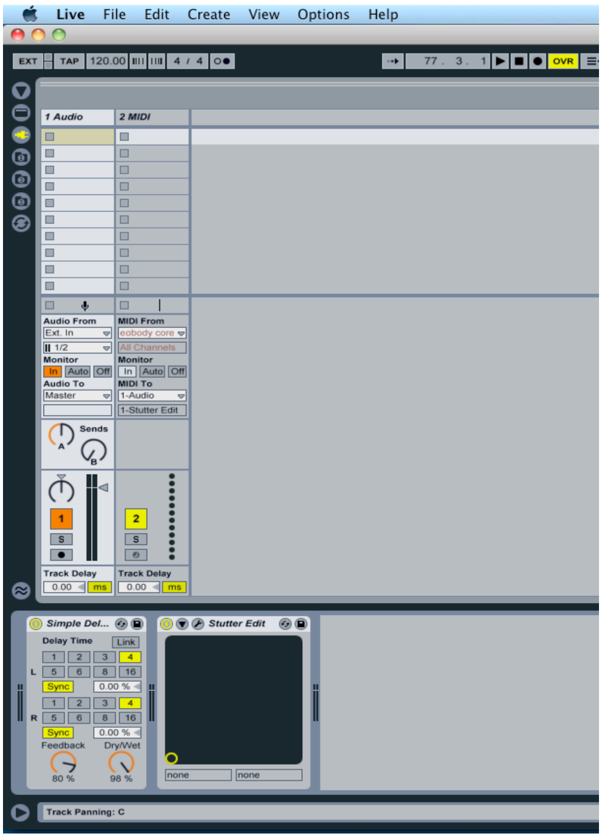


Figure: 50 Ableton set up for guitar pad sound (screen shot)

The resulting sound is then passed through a second delay (Crystallizer by Sound Toys) (see Figure 51) via an auxiliary send, which splices the sound in a granular manner and applies minute pitch change to fragments of the sound as well as delay. The resulting sound is fed back on itself using the recycle feature in the plug-in, in order to create further delays of the same sound.

Figure: 51 Sound Toys delay (screen shot)

The sound from the Crystallizer plug-in is then passed on to a dense reverb sound via a second auxiliary channel (see Figure 52).

Figure: 52 dense reverb plugin (screen shot)

The resulting sound can be heard in the video I have included on the DVD-ROM titled guitar pad.mov (Appendix A).

To manipulate the sound further and to create the effect of the sound stuttering, I passed the sound through a plug-in made by Izotope called Stutter Edit (see Figure 53). I have programmed into this effect a number of stutters and jitters that fragment the guitar pad resulting in both rhythmic and non-rhythmic alterations of the sound. The stutters are triggered via the sensors on the guitar.

Figure: 53 Stutter edit plugin (screen shot)

The resulting effect can be heard and observed on the included DVD-ROM, entitled Stutter.mov (Appendix A). All processes shown in the videos are performed live - the sounds are not pre-recorded.

The sensors on the guitar have also been used to trigger samples. For example, I have sampled harmonics played on the guitar, which are in turn triggered via the sensors on the guitar during recording and performance. These are played alongside actual harmonics and melodic lines being played on the guitar strings. This can be seen at 01’44” on the DVD-ROM (Appendix A) entitled Hyper-Guitar Intro.

The Tarang instrument, which occurs at 14’18” into the composition and the guitar harmonics described above were created by using a piece of software called Samplit produced by Soundlib Software (see Figure 54). Samplit is designed for creating sampler instruments and allows you to record, import sounds and map them into velocity layers. It also allows the creation of layers with different articulations, which can then be key switched. I created multi-sampled Tabla sampler patches for each note of the Raag. Each note has eight velocity layers ranging from very quiet to very loud. This was done in an attempt to create as realistic sound as possible, as using just one sample per note does not sound convincing. When an instrument is struck, strummed or plucked with varying degrees of force the timbre or tone of the instrument changes slightly. There is also an effect on the natural decay time of an instrument dependent on how hard it has been played. You can see the different velocity layers on the DVD-ROM movie entitled Samplit.mov (Appendix A). The resulting sampler program was then exported as a Native Instruments Kontakt sampler patch. Please see DVD-ROM movie titled Tabla Tarang.mov (Appendix A).

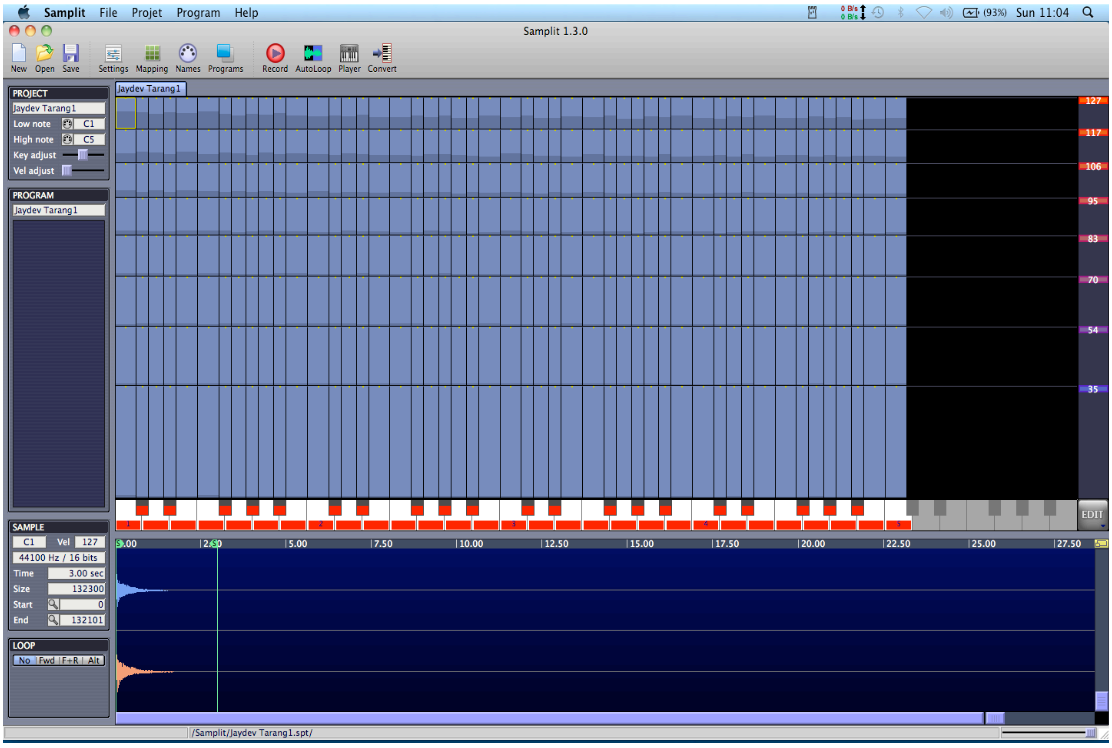


Figure 54: Samplit software (screen shot)

4.6 Final section of composition

The final section of the composition is inspired by Gandhi's Homespun campaign. The cotton mill sounds in this section originate from a recording I made of a weaving loom within the Huddersfield University's Textile Department. This recording was later manipulated to create a rhythm that fits the piece and forms part of the drum and bass section which a can be heard at 19.00 minutes into the recording. Triggering the drum samples via the guitars sensors and playing the rhythm guitar parts at the same time influenced the rhythmical feel in this section. The speech at 19.48 minutes is taken from the 1982 biographical film "Ghandi" [43] which stars Ben Kingsley as Ghandi.

The lyrics in this section are written and performed by Paul Stevens (A.K.A: The Rev Paul) who is a poet from Greater Manchester. Stevens worked from a brief I gave him detailing what this section was about and was given some background history regarding the subject matter of the piece. Paul then did his own research and wrote the lyrics in response to his findings. Below is a transcription of his lyrics

[43] http://www.imdb.com/title/tt0083987/

and Appendix B is a description Paul wrote detailing the process he undertook to arrive at the lyrics.

Where the land is full of devils
Do not buy what you already own
Or trade at the musket barrel
When the sky is dark with ghosts

From Delhi across to Darwen
Every home can clothe themselves
From where they trade in stolen land
To where they trade in stolen souls

and the cotton fields flow with the blood of gods
and warm winds know of the cries that they carry
and the shabby cloth floats from the sealed land
where the same voices vent for release from the toil

And the sacred cows don't dwell in the field
Sent to slaughter at auctions and exchanges
A nation balanced on snide scales
Oppression measured by the bale

Cut your cloth accordingly
Cut the crap and concentrate
Or cooperate with evil
With the lap dogs at the gate

Who are kept on linen leashes
Who are kept on dark spun tethers
To be released into the village
Where the people stand together

and the cotton fields flow with the blood of gods
and warm winds know of the cries that they carry
and the shabby cloth floats from the sealed land
where the same voices vent for release from the toil

And the sacred cows don't dwell in the field
Sent to slaughter at auctions and exchanges
A nation balanced on snide scales
Oppression measured by the bale

Traverse the trade trail to spring vale
Thin shawl against the autumn freeze
A country squeezed, empire and greed
Another people on their knees

The ocean sheets are stained with dye
All taint and valueless dismay,
Another show of petty strengths,
To those who dare stand in the way

and the cotton fields flow with the blood of gods
and warm winds know of the cries that they carry
and the shabby cloth floats from the sealed land
where the same voices vent for release from the toil

And the sacred cows don't dwell in the field
Sent to slaughter at auctions and exchanges
A nation balanced on snide scales
Oppression measured by the bale

Lyrics by The Rev Paul

With the composition of *Homespun*, I have created substantial work that has allowed me to explore numerous technical and musical possibilities. It has, and will continue to help me to develop further the playing techniques I have developed. The method of composition has been a combination of improvisation and structured composition, with the two methods being brought together using Logic Pro 9 during the editing and arranging parts of the process.

Practicing parts of the piece for performance will develop dexterity in both my left and right hands. I now have rhythmic, harmonic and melodic material to concentrate on which tasks me with finding the ways and means of playing the different elements at the same time. Physically, it is probably impossible to recreate the composition exactly as recorded in a live situation as a solo artist. This fact was made clear to me when I performed a section of the piece at Huddersfield University as part of the Electric Spring festival in February 2012. Preparation for and performing at this event highlighted that I still have much work to do in terms of developing co-ordination and finger independence. Improvements in these areas will facilitate more accurate, fluid and much tighter delivery. This experience has also indicated to me that I need to develop different approaches when composing and arranging for live recitals.

5 Conclusion

The overall aim of this research was to ascertain the feasibility of designing and building an ergonomic hyper-guitar which, extends the guitars sonic range and introduce methods of sound manipulation through the use of sensors. The specific research objectives were:

- Identify the ergonomics of electric guitars in relation to playing comfort.
- Design an ergonomic guitar based on the above findings.
- Identify sensor technology that would be suitable for translating gestures into MIDI information.
- To develop performance techniques and the composition of a musical piece that highlights the instruments capabilities.

5.1 Research objective 1: Guitar ergonomics

My personal findings through experimentations helped me to obtain the ideal angle for the neck, which has resulted in an instrument that is tailored to my needs in terms of comfort and reducing stress in the shoulders, elbows and wrists. For me at least, with traditional guitar body shapes, it is difficult to facilitate an appropriate neck angle. Also the inclusion of a headstock causes the neck to dive towards the ground. This means that the arm is required to support the weight of the neck in order to position it correctly. This causes stress in the elbow and wrist and restricts movement. It is therefore necessary for the guitar body to be redesigned and remove the headstock out of the equation in order to achieve playing comfort.

Even with the above in mind, and as Lospennato states that the design of commercially available electric guitars has not changed much since its inception in relation to ergonomics. Many guitars I have played over the years have a forced me into uncomfortable playing positions.

There are guitar designs in existence that are constructed with ergonomics in mind, however, these instruments are few and far between. Ergonomic guitars that do exist are mainly designed and built by custom builders and are therefore extremely expensive and rare. They are regarded as specialist instruments and there is only a very small community of guitarists that have taken these concepts on board.

There are no major manufacturers of guitars supporting ergonomic design in their instruments. This could be due to the fact that there is an accepted norm amongst guitarists as to what a guitar should look and sound like. Many spend years trying to perfect vintage sounds, as a result there is a growing market for replica guitars that are very accurate copies of instruments that have been built from the 1950s onwards. These replicas themselves can be very expensive, people are willing to pay large amounts of money for them yet, there are few that would spend similar amounts of money on ergonomically designed guitars, dismissing them for aesthetical reasons.

It is with the above in mind that I have presented the instrument I have designed to a number of guitarists. Some have responded by saying that, they find the guitar very comfortable and easy to play and have:

A) Understood the ergonomic principles behind the design and

B) Appreciate the ergonomic flaws inherent in traditionally designed guitars.

However, the small number of guitarists who have tried the instrument have stated that they would prefer it if the guitar looked more like a Gibson Les Paul or Fender Stratocaster, indicating that traditional aesthetics are still important to some.

5.2 Research objective 2: Design an ergonomic guitar

In relation to my personal needs regarding guitar ergonomics, the Mistry-hyper guitar that has been built fulfills the requirements I set out to achieve. The instrument sits very comfortably and aids in obtaining a good posture and positioning of both the left and right hands. Through constant use I have noticed that there is far less stress and fatigue in my shoulders, wrists and back. I am able to play the guitar for much longer periods of time without experiencing the same aches and pains as I used to when playing a conventionally designed solid body electric guitar. Another design goal was to reduce the weight and this has been done successfully, which also aids in increasing comfort when playing for long periods of time. Coupled with the fact that there is no headstock, the guitar balances perfectly, which means that the fretting hand is no longer supporting the weight of the neck. This means that the fretting hand has far more freedom of movement, reduction in stress in the wrist and elbow and which, facilitates more efficient playing.

The positioning of the sensors work extremely well, enabling good access to both the strings and sensors. The results of this are that moving from strings to sensors and playing the strings and sensors at the same time is effortless.

A number of guitarists have tried the instrument and they state that the guitar is easy to play, like the way the instrument balances and are excited by the concept of being able to trigger MIDI devices via the sensors.

However, observing other musicians play the instrument and receiving comments from a couple of them, has informed me that, although the positioning of the sensors work perfectly for me, the placement of the sensors may have to be adjusted to fit individual musicians. This would entail taking into account the size of their hands and the position they find most comfortable to play in. This will ensure the ergonomic principles that inform the guitar are maintained. An alternative would be to design a method, which enables the end user to adjust the positioning of the censors themselves. This will enable the user to make adjustments as they become familiar with the instrument and find what's best for them.

5.3 Research objective 3: Identify sensor technology.

The choice of sensors was based on examining the types sensors that are used for electronic percussion. I compared the two most common types of sensors used, which, are piezo pickups, and force sensitive resistors. I found advantages and disadvantages with both types.

With piezo pickups I found that they:

- Respond very well to rapid transients and enable the playing of fast and intricate percussion parts.
- They are only capable of detecting transients, and cannot register sustained notes.
- Are readily available and cheap.
- Have to be handled with care, as the connections can be fragile.
- Because they operate by sensing vibrations, they need some form of acoustic isolation from each other and the guitar body. Without this isolation there is unacceptable crosstalk between sensors.

With force sensitive resistors I found that they:

- Respond well to rapid transients but not as effectively as piezo pickups.
- Are capable of detecting transients and sustained notes.
- Are not as readily available.
- Are fairly robust.
- Translate velocity information well.
- Do not need acoustic isolation from each other as they work by detecting pressure.

Force sensitive resistors were chosen rather than the piezo pickups for two main reasons. The first of which is the fact that they can detect sustained notes and secondly they do not need acoustic isolation from each other. Their durability was also another factor in choosing them.

The sensors perform well and are very responsive. The only issue with them is that there is a slight latency when playing extremely fast. This is due to how quickly an individual FSR responds to multiple strikes in rapid succession. A workaround for this problem is to have the same sound, for example, a snare assigned to two adjacent sensors and alternating strikes between them. This works very effectively but has the disadvantage of using up two pads for one sound. Also, there has to be two separate versions of the audio file of the same sound on each pad in order to avoid what is termed as a 'machine-gunning' effect that plagued early sample based electronic percussion. However, even with the latency in most cases the triggers perform exceptionally well and it is only at extreme speeds do you notice any problem.

The sensors are covered with neoprene pads in order to protect them and secondly to act as a playing surface. Although they are adequate in protecting the sensors, they do not give the same response one would get when playing hand percussion such as congas. The fingers do not bounce back of the pads in the way they would off a real instrument. I am also missing feeling the vibrations one experiences from an instrument such as congas. The pads feel a little unnatural compared to the feel of the rest of the instrument and they have taken me a little while to get used to. However, I have experienced the same types of issues from other hand played electronic percussion instruments such as the Roland HPD-15 Handsonic. The Handsonic, though responsive, is lacking in the same areas as described above.

I will continue to research and test other materials for the pads in order to improve performance in terms of feel and response.

5.4 Research Objective 4: To develop performance techniques and composition

Initially it was my intention to compose the music in response to the techniques that I was developing. But early on in the process, I found that my techniques were not advancing quickly enough in order to compose the music that I would be satisfied with. It was through the advice from my supervisor Prof. Monty Adkins that, combining the new techniques I had already developed with compositional methods I have used before, would serve me best at this point in the process. The result of this is that, I have created a body of work that I can now practice and drill. This has had the effect of focusing my technique development in relation to the composition. I have found that my technique is now developing at a faster rate and I am more able to compose in the way that I had intended to in the first place.

Another element that informs my practice in terms of composition is sound design. At the moment I am using the Roland VG-99 to create the guitar sounds. This is combined with processing the resulting sounds with computer programs that allow me to manipulate the sound further. The main reason of using the VG-99 is that, as it is a physical modeling device, I am able to apply pitch shifting to each individual string, This enables me to create guitar tunings that would otherwise be impossible on a regular guitar. Although most of the time the pitch shifting algorithms within the VG-99 are accurate, there are occasions when playing extremely fast, the unit struggles to maintain the pitch on certain strings which can create unwanted artifacts. I will continue to investigate alternative methods to achieve the same pitch shifting effect.

The composition has also allowed me to explore combining playing percussion parts at the same time as playing guitar parts and this is an area I will be developing further. Some of the techniques I have developed so far seem to mimic certain aspects of Tabla playing. I will therefore include the study of Tabla playing as an integral part of my practice regime. This I believe will allow me to gain greater independence in each finger, increase speed and efficiency plus increase stamina.

Other areas for further research and study that I wish to explore include:

1. The study of Indian classical and folk music styles. Then applying what I learn into a contemporary context. I feel I have started this process with my composition and would like to explore the possibilities further.

2. Complementing learning tabla techniques, by studying other forms such as Flamenco guitar. This is a very percussive style of guitar playing, as guitar parts are accompanied by percussion sounds that are tapped out on the guitar body. This would further enhance my timing, dexterity and accuracy plus adding another dimension to my compositions and performances.

3. Research other methods of manipulating the guitar sound through the use of computer programs such as Max/MSP manufactured by Cycling 74. Max is an environment that allows the user to develop unique software applications by patching objects together for audio and signal processing. I

see this as one possible way of eliminating the need for the Roland VG-99. This could be achieved by taking advantage of the Hex pick up which is fitted to the guitar. This will allow me to take the signal from each string and apply individual processing to each stream of audio such as pitch shifting. This will allow me to create the different guitar tunings I wish to use. The above is only one example of the possibilities with the Max-programing environment. Learning to use this piece of software would enable me to explore many new sonic possibilities.

5.5 Summary

Overall I feel that I have achieved my objectives and I have developed a new mode of solo performance and composition methodology for both my studio-based work and live performance work. I have an instrument that is unique in terms of its capabilities and I am enjoying an enhanced playing experience due to the ergonomic features incorporated into the guitar. By extending the capabilities of the instrument through the inclusion of sensors, I have the scope to manipulate the sound, play accompanying parts such as bass and melodic lines as well as percussion. I feel that I am only scratching the surface so far in terms of composition, technique and technology with this instrument. I am excited by the prospects of exploring and further developing a new mode of expression.

Appendix A: DVD-ROM contents

The DVD-ROM comprises seven short movie files demonstrating the hyper-guitar and its related performance techniques.

1. Hyper-guitar introduction.mov
2. Drum'n'bass examples (DnB2.mov)
3. Guitar Pad.mov
4. Pad effects.mov
5. Samplit.mov
6. Stutter.mov
7. Tabla Tarang.mov

Appendix B

Rev Paul's analysis and process of the Homespun Lyrics. Written by Paul Stevenson.

Writing the lyrics to Jaydev's piece was a challenge for me as I have little experience of writing lyrics to existing pieces of music and of writing to specific themes presented to me. Although I often work with musicians, what tends to happen is that they present musical ideas to me and I select the most appropriate lyric from a library of pre-existing poetry and then work to adapt it to the music.

The section of his composition that Jaydev offered me to work on consisted of two main themes, one at approximately double the speed of the other. The choice was therefore to either write everything to the same meter and the recite the "Chorus" section (the repeating section) essentially at half speed in relation to the tempo of that section or to write a piece incorporating the tempo change, i.e. double the number of syllables over the repeating section, and I chose to do the latter to emphasise the contrasts between the sections in the music.

The writing process was done in two stages. Initially I worked from an early, skeletal version of the piece, fitting the syllabic structure around the basic rhythm, and then later, when I had access to a more "filled out" arrangement, I amended the lyrics slightly to mirror nuances in the music, which had been added.

When it came to recording we took a sectional approach, with me recording, initially, three full versions of the piece, and then at a later date, re-recording sections which Jaydev thought could be done more successfully. Unsurprisingly the "Chorus" section was the hardest to complete, given the speed, although I'm sure that it wouldn't have provided a problem to someone more adept at "Hip hop" style delivery than I am.

In terms of developing the theme of the poem, my main source was this article from the BBC about Gandhi's visit to Spring Vale in 1931 http://www.bbc.co.uk/news/uk-england-lancashire-15020097

I worked from the premise that the Davies's invitation to Gandhi was a cynical attempt to shame him into abandoning his Homespun Campaign, by exposing him to the ire of mill workers in Lancashire. As it turns out, the plan backfires as the locals take him to their hearts and sympathise with his campaign, highlighting the commonality of the experiences and hardships suffered by working people of the time in India and the UK.

The first verse deals with the homespun campaign, the moral rightness of it and the similarities between the way people's labour is used in capitalism in both a domestic and imperial context.

The second verse deals with the pressures that Gandhi's campaign came under in terms of challenges from the British Military and by Indian collaborators, and the need for unity in the face of this.

The third verse deals with Gandhi's visit to Spring Vale and the empathy developed between him and the British Mill workers.

The "Chorus" uses the metaphor of the Hindu sacred cow to demonstrate how entire cultures are stripped of their identity to be become, in Marxist terms, "Means Of Production" in an economic system institutionally biased against their interest, which in turn negates the cultural identity of people across the world, both in the "developed" countries and in the developing world which those economic powers seek to exploit.

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